

The background of the slide is a large, irregular hexagonal grid. The hexagons are colored in several ways: some are green, some are purple, some are pink, and some are brown. The colors are distributed across the grid in a way that suggests different regions or states within a simulation. The text is overlaid on this grid.

Simulating Population and Stressor Interactions with HexSim

**Nathan H. Schumaker
Joshua J. Lawler
Julie A. Heinrichs**

Introduction

This talk is mostly about methods.

You will be introduced to a new individual-based model (HexSim).

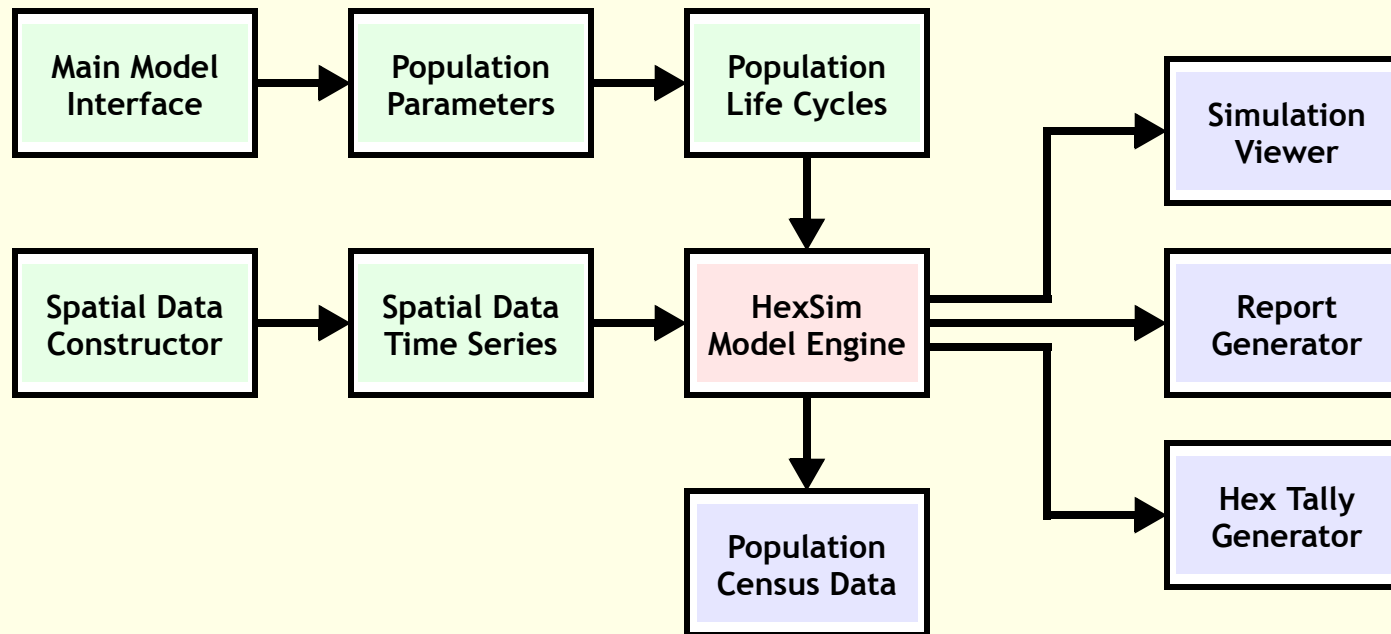
The model can simulate many diverse and complex interacting stressors.

Preliminary results are shown, but this work is a “proof of concept”. Realism will be added later.

Thoughts To Take Away

- Concepts:* Questions you might ask with these tools
- Mechanisms:* How to use the tools to get at the questions
- Expectations:* The kinds of outputs and insights you can get from the tools

The HexSim Model



Model Inputs:

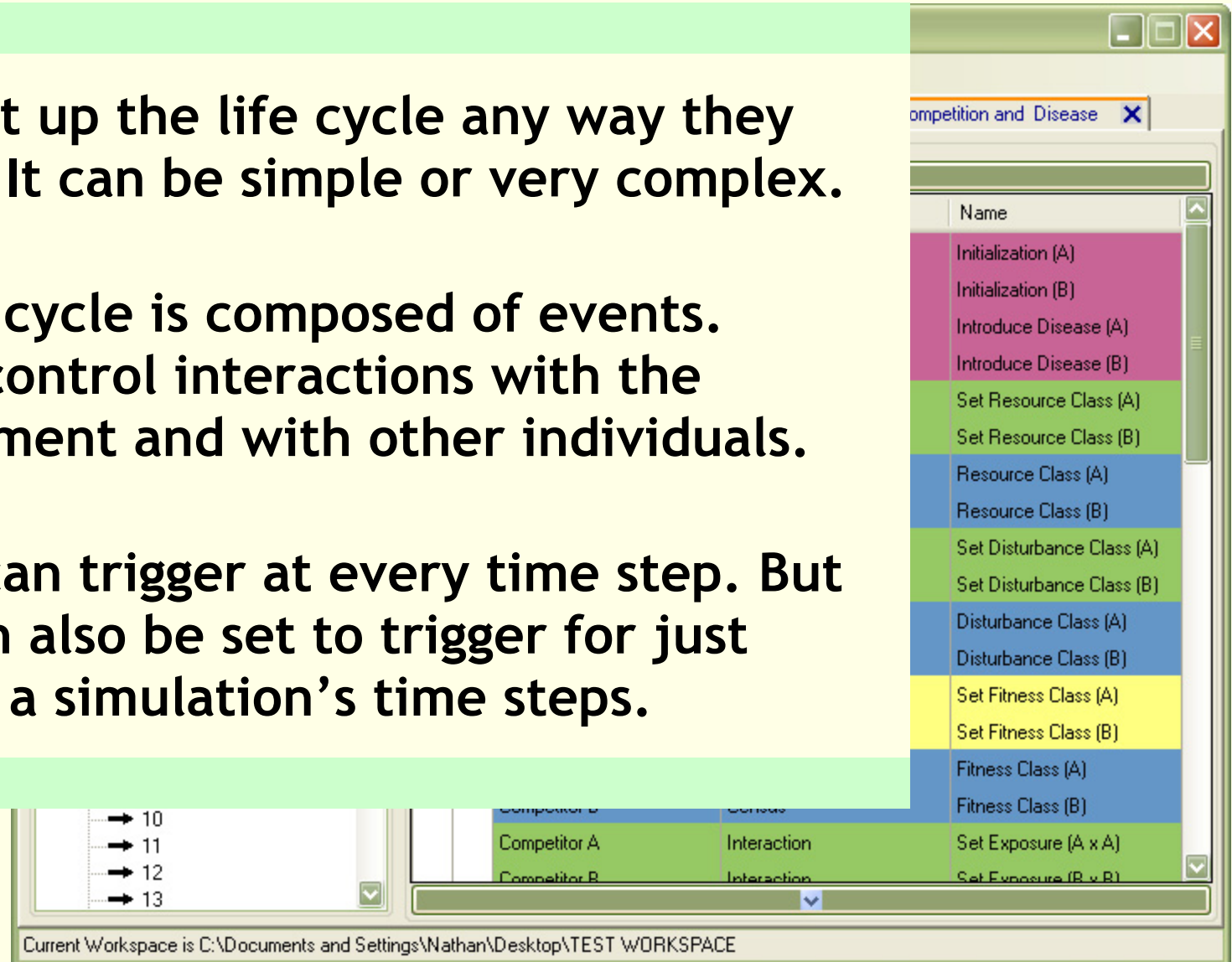
- XML Scenario Data
- Spatial Data

Model Outputs:

- Population Census Data
- HexSim Log File

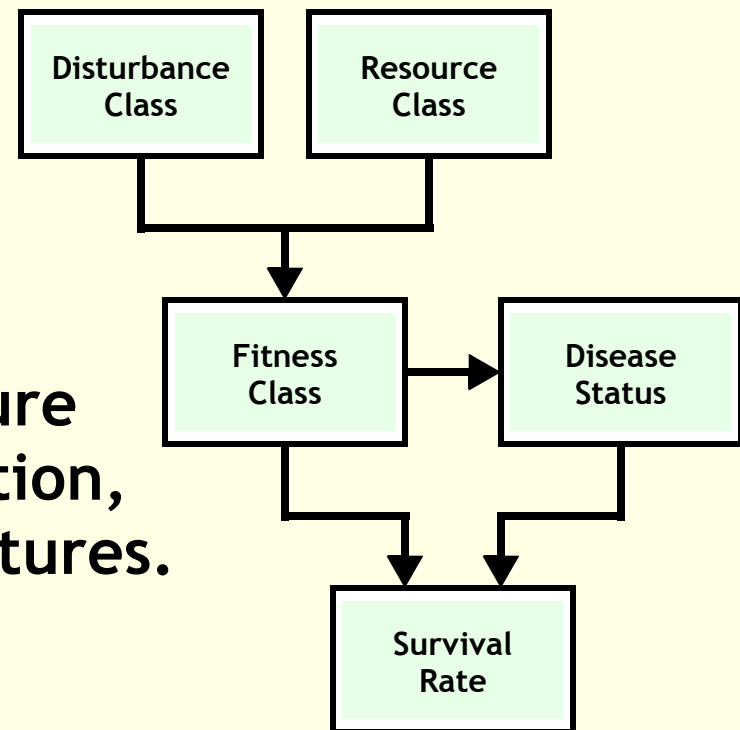
HexSim Life Cycle and Events

- Users set up the life cycle any way they choose. It can be simple or very complex.
- The life cycle is composed of events. Events control interactions with the environment and with other individuals.
- Events can trigger at every time step. But they can also be set to trigger for just some of a simulation's time steps.



HexSim Traits and Interactions

- Traits are tied to the environment, are probabilistic, or are genetic.
- Probabilistic traits can change based on probabilistic and environmental drivers.
- Environmental traits can capture resource acquisition, competition, exposure, and many other features.



Example: Two Traits Control A Third

Switch Both | Competitor A

Properties

Range Data

Traits and Accumulators

Affinities

Description

Traits

Disease Status
Disturbance Class
Exposure Class
Fitness Class
Resource Class
Stage Class

Accumulators

Age
Resources
Exposure
Disturbance

Switch Both | Transition (Set Fitness Class (A))

Name

Set Fitness Class (A)

Properties

Transitions

Description

Population

Competitor A

Transition Trait

Fitness Class

Stratification Traits

☐ Disease Status
☒ Disturbance Class
☐ Exposure Class
☐ Fitness Class
☒ Resource Class
☐ Stage Class

Recover

Close

Switch Both | Transition (Set Fitness Class (A))

Name

Set Fitness Class (A)

Properties

Transitions

Description

Transition To ⇒ Combinations ↓	Low Fitness	Moderate Fitness	High Fitness
▶ Undisturbed, Resource Level 0	0.5	0.5	0
Undisturbed, Resource Level 1	0	0.5	0.5
Undisturbed, Resource Level 2	0	0	1
Disturbed, Resource Level 0	1	0	0
Disturbed, Resource Level 1	0.5	0.5	0
Disturbed, Resource Level 2	0	1	0

1 of 1

Add

Import

Export

Delete

Recover

Close

Example: Three Survival Events

The image displays three overlapping software windows, each titled "Switch Both | Survival (...)", showing survival data for different classes. Each window has tabs for Properties, Rates, Description, and Output. The "Rates" tab is active in all three.

Window 1: Survival (Stage Class (A))

Name: Stage Class (A)

Survival ⇒ Combinations ↓	Mean Rate
▶ Stage 0	0.4
Stage 1	0.6
Stage 2	0.8
Stage 3	0.8
Stage 4	0.6
Stage 5	0.4

1 of 1

Add Import Export

Window 2: Survival (Fitness Class (A))

Name: Fitness Class (A)

Survival ⇒ Combinations ↓	Mean Rate
▶ Low Fitness	0.5
Moderate Fitness	0.75
High Fitness	1

1 of 1

Add Import Export

Window 3: Survival (Disease Status (A))

Name: Disease Status (A)

Survival ⇒ Combinations ↓	Mean Rate
▶ Healthy	1
Infected	1
Sick	0.7

1 of 1

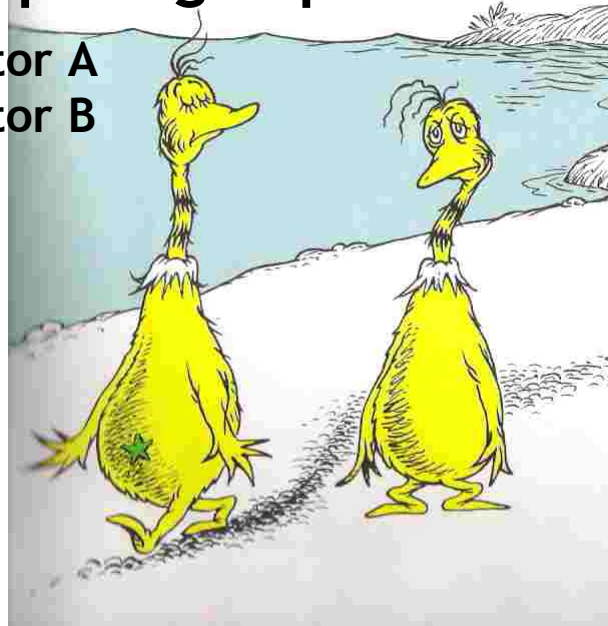
Add Import Export Delete

Recover Close

Our System Of Interactions

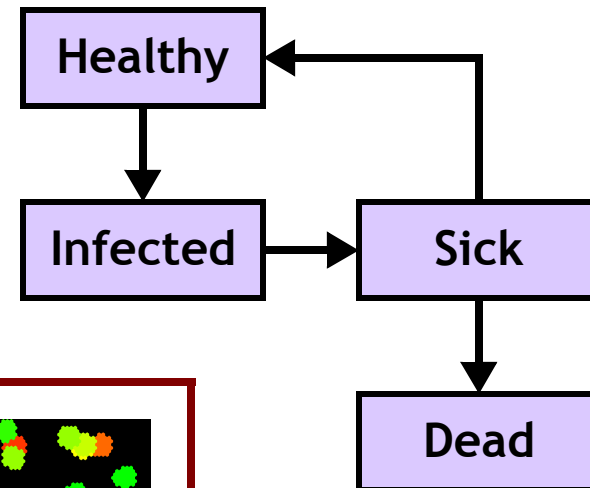
Two Competing Populations:

- Competitor A
- Competitor B



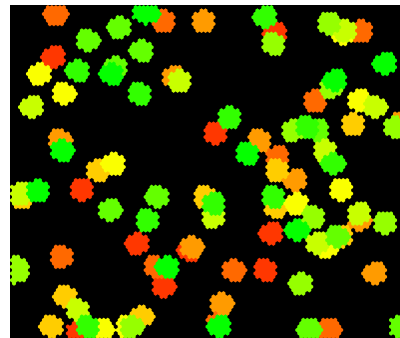
Disease Process:

- Can Spread from A to B, or
- Cannot Spread from A to B

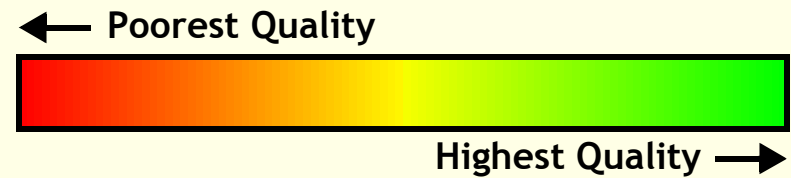


Disturbance Process:

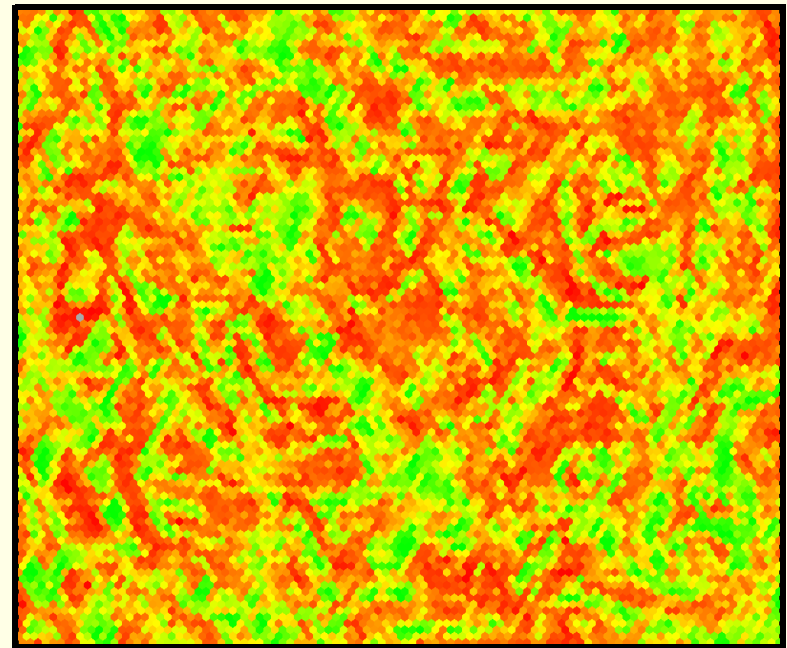
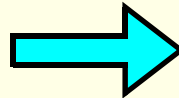
- Dynamic in Space and Time
- Influences Vital Rates



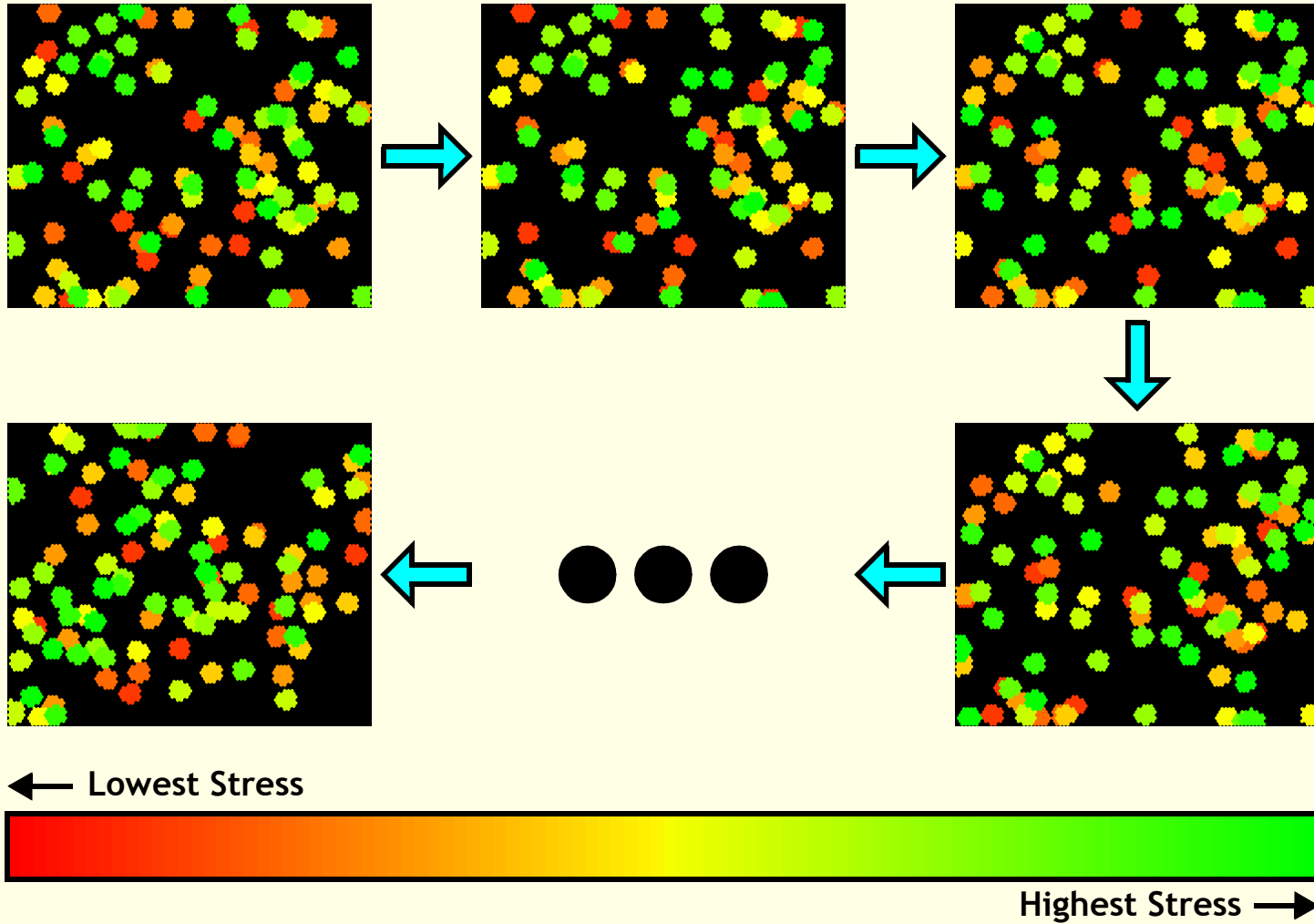
A Single Habitat Map



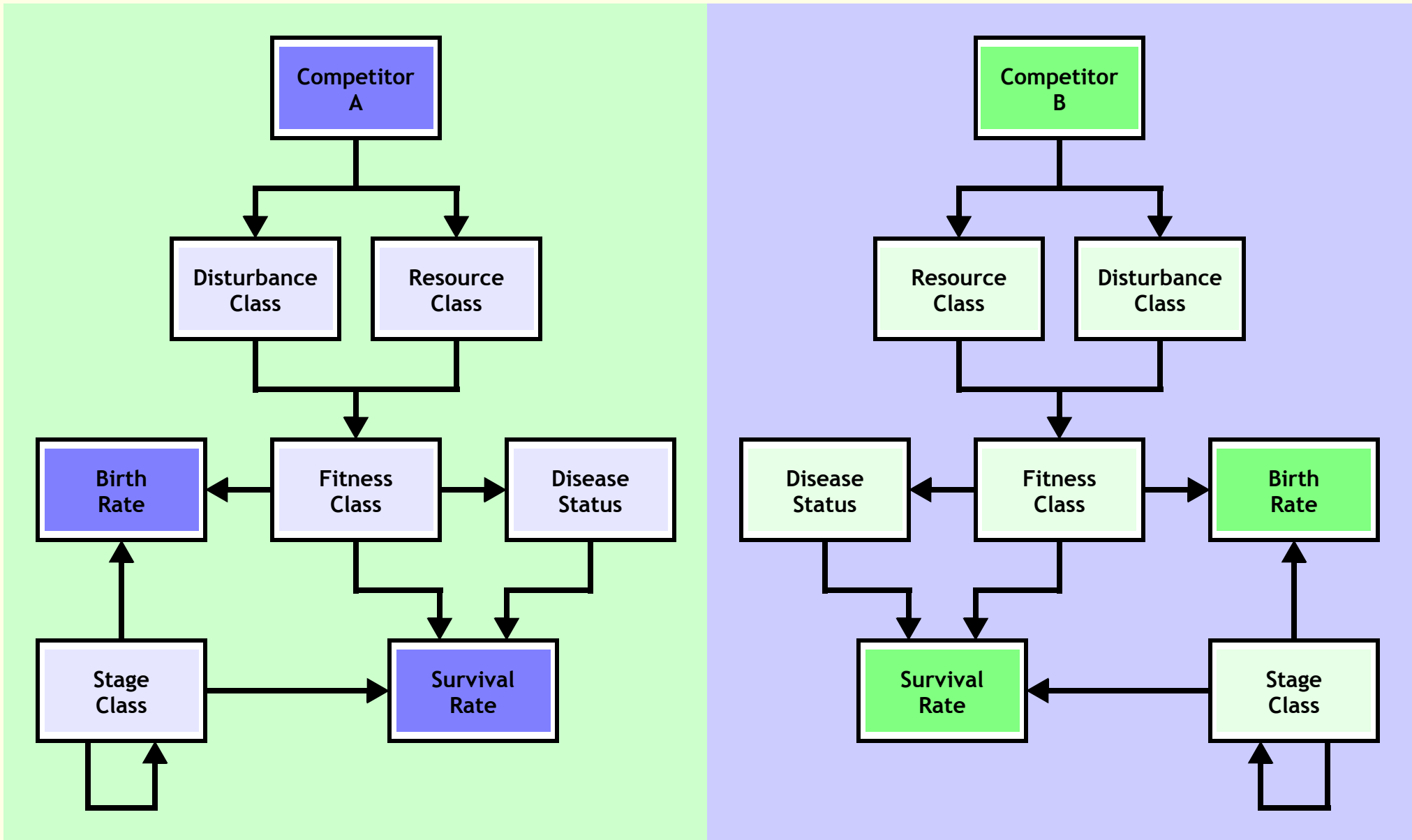
100 x 100 hexagons



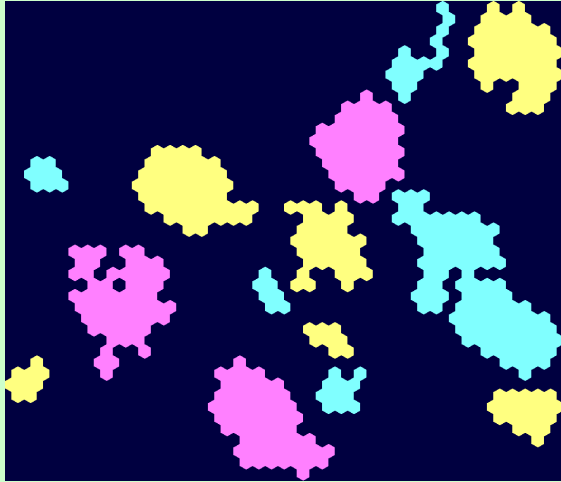
100 Disturbance Maps



Two Competitors



Other Simulation Details



Individuals aggregate into groups of 1-50.

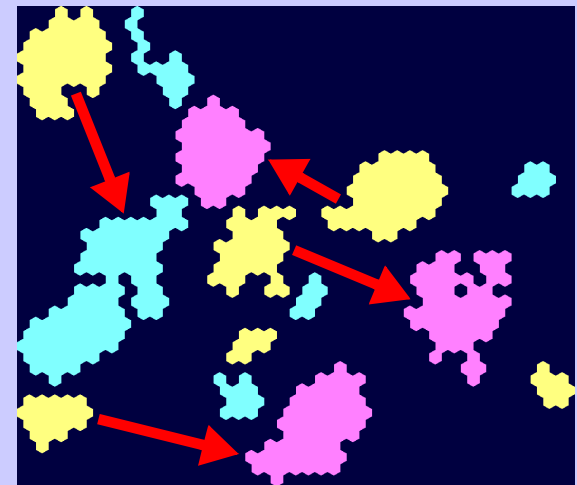
All individuals have equal resource needs.

No environmental stochasticity.

Disease is spread by contact with sick or infected individuals.

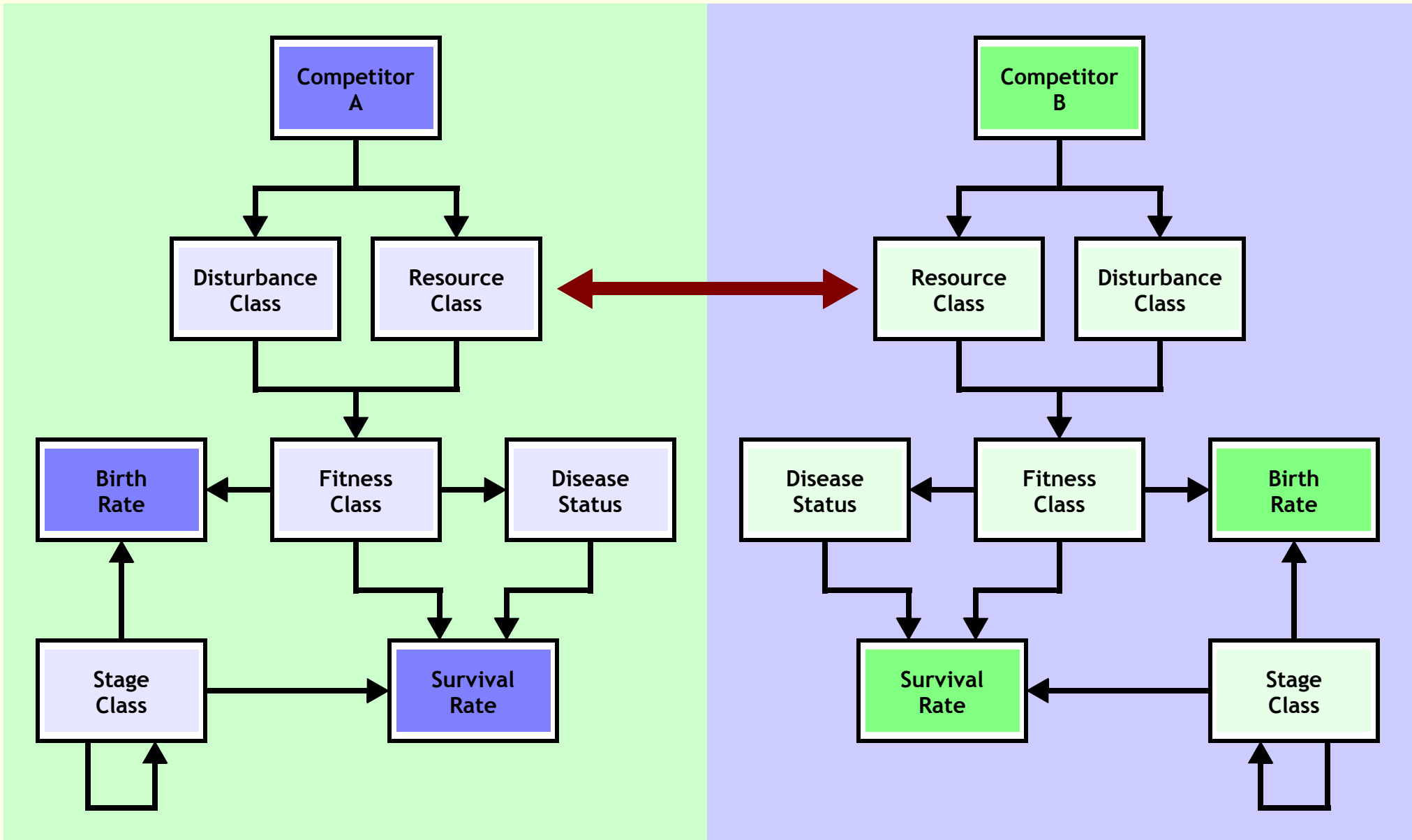
Disease has 3 stages: healthy, infected, sick.

Recovery is fitness-dependent.



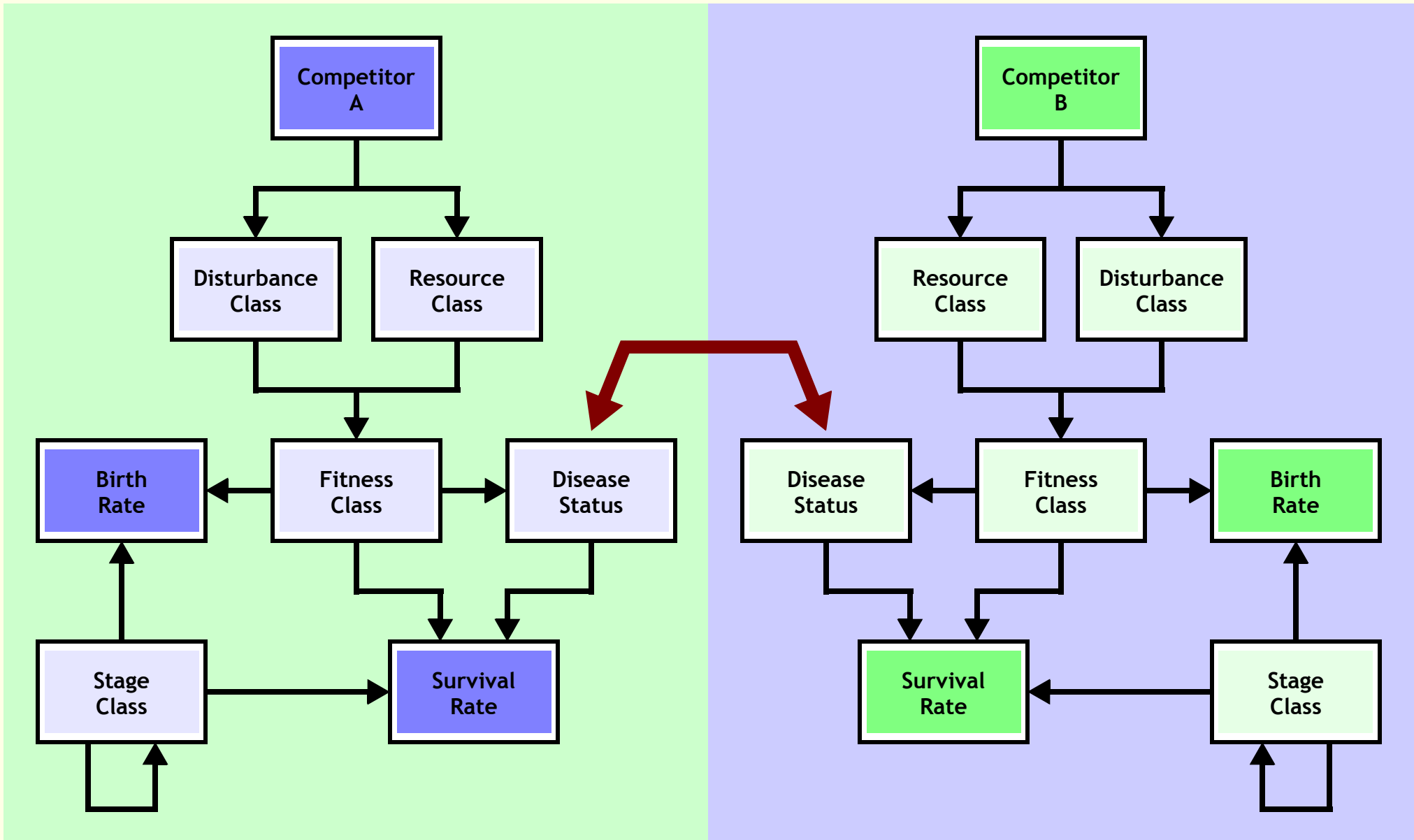
Experiment 1

Add Competition (with / without disease)



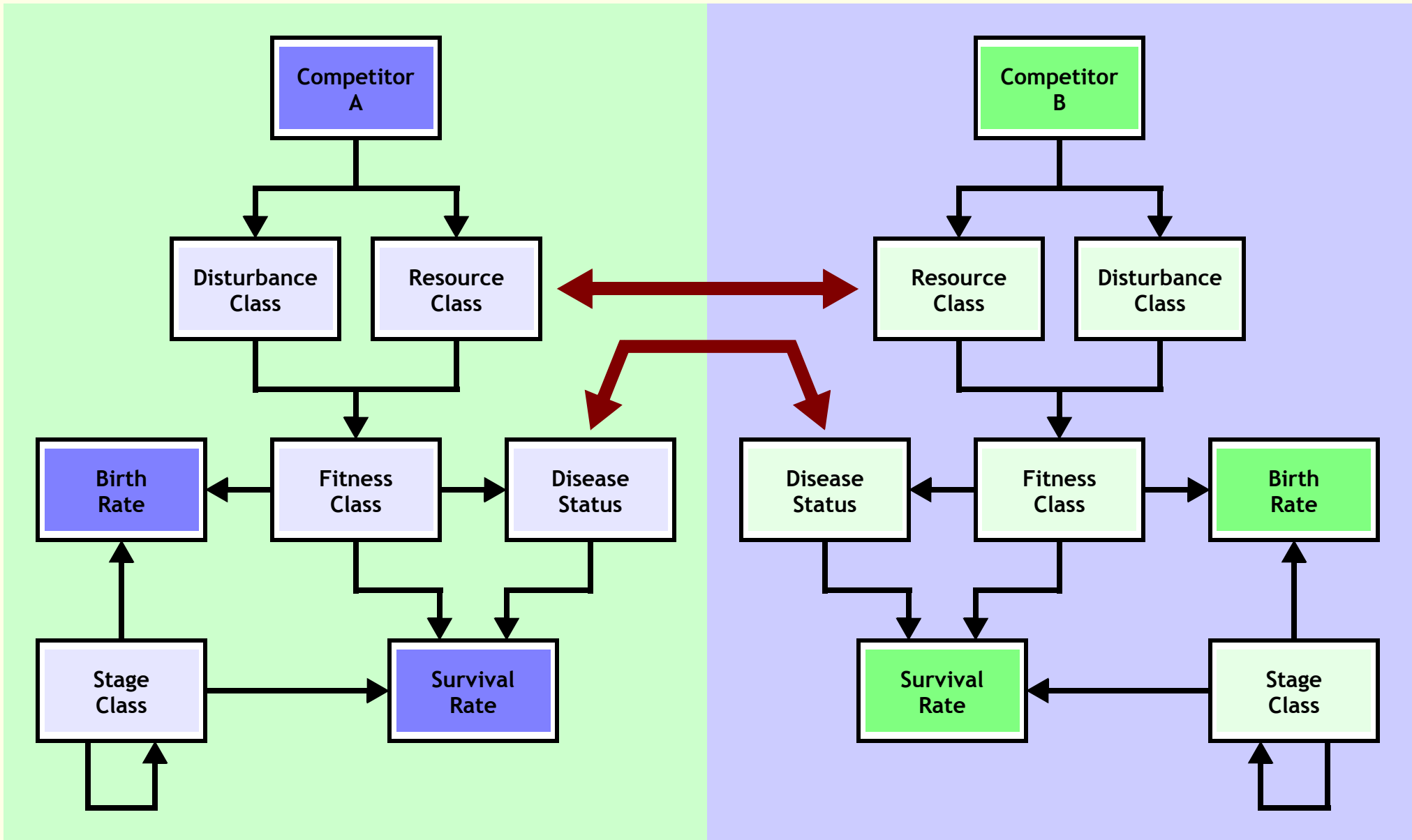
Experiment 2

Add Disease Sharing



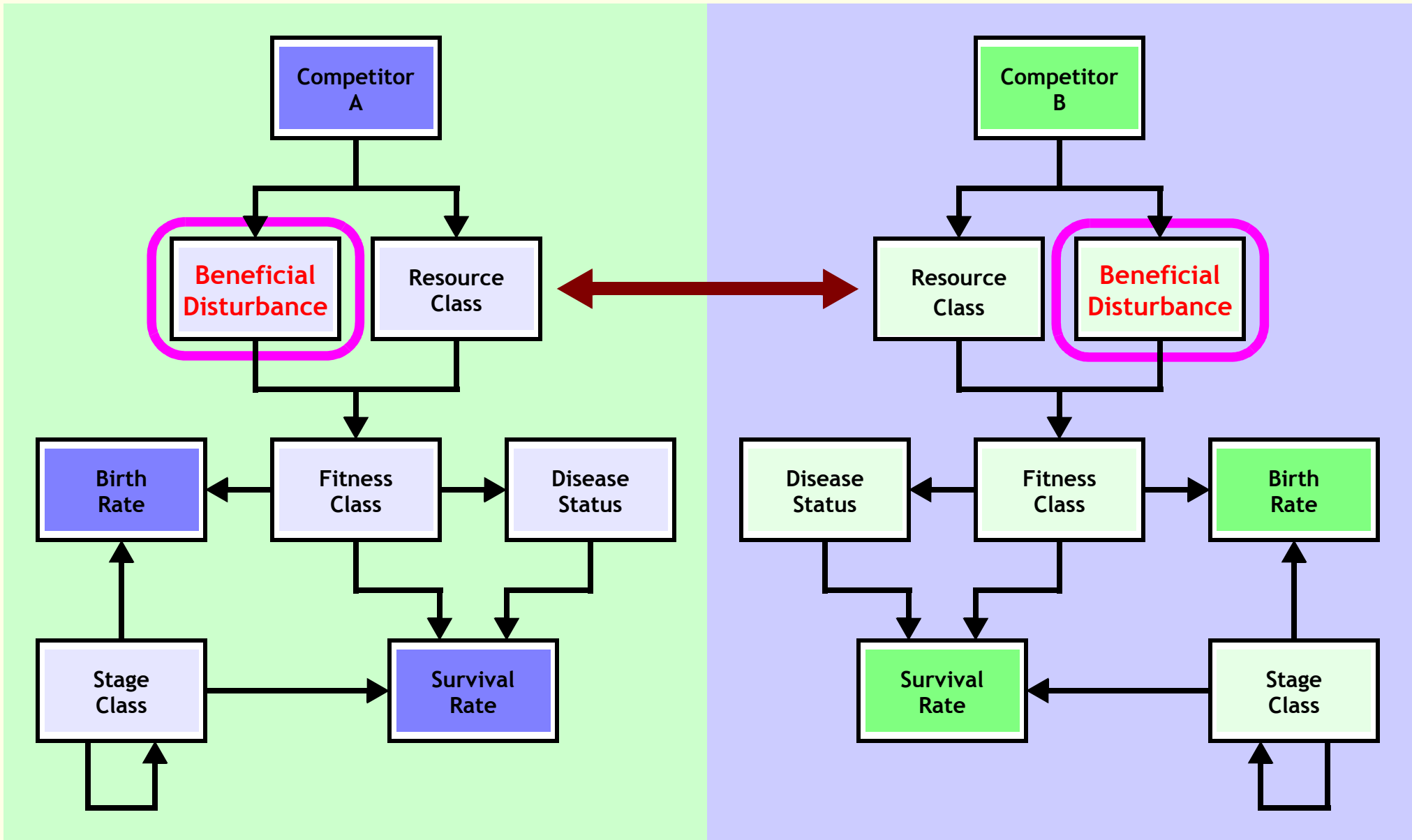
Experiment 3

Add Competition and Disease Sharing

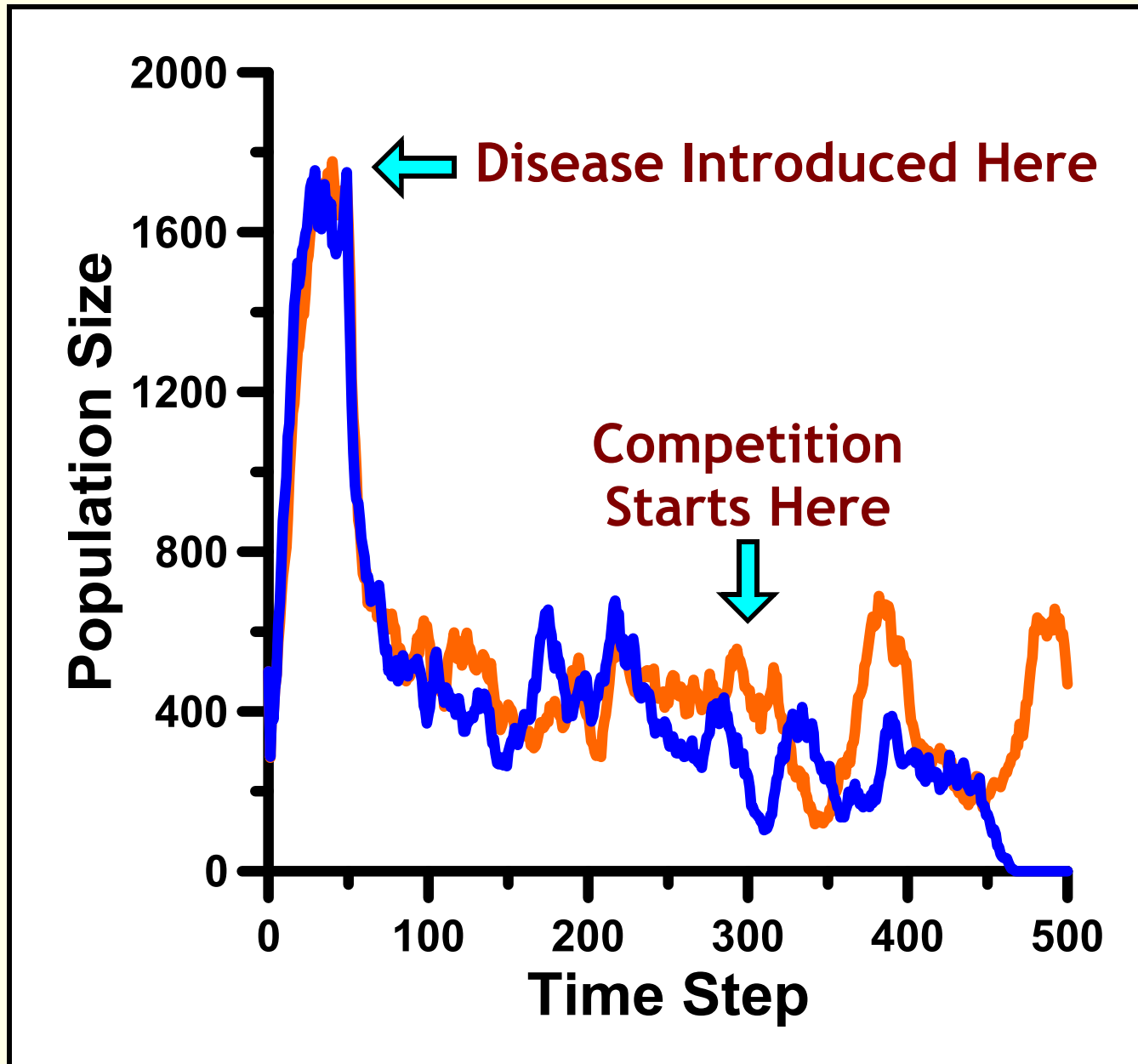


Experiment 4

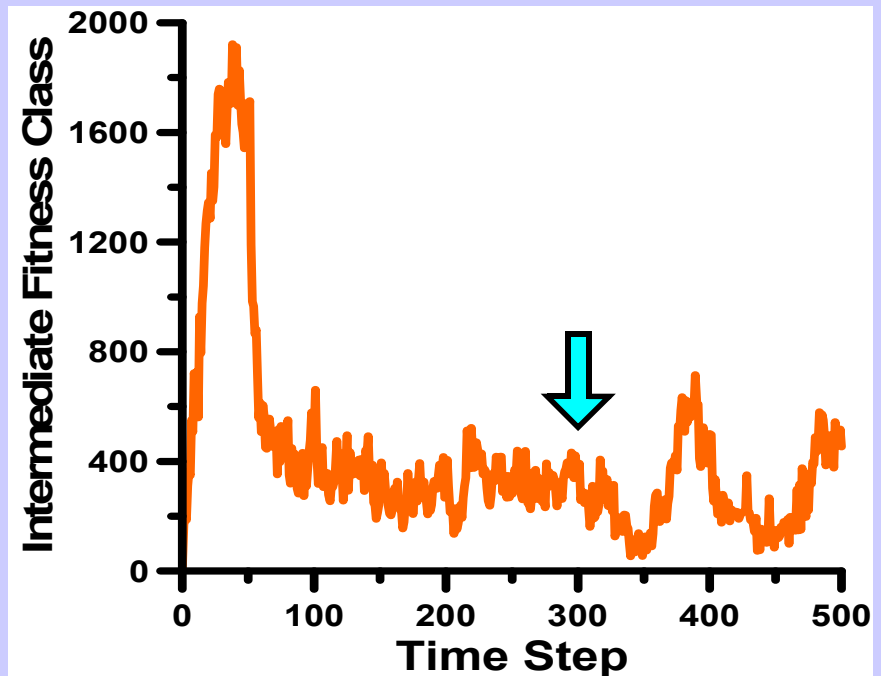
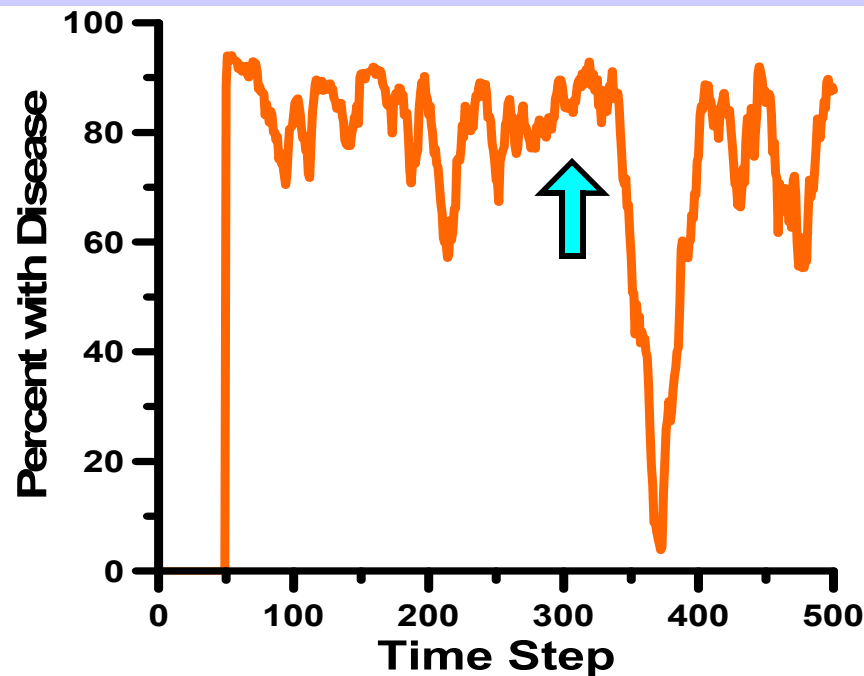
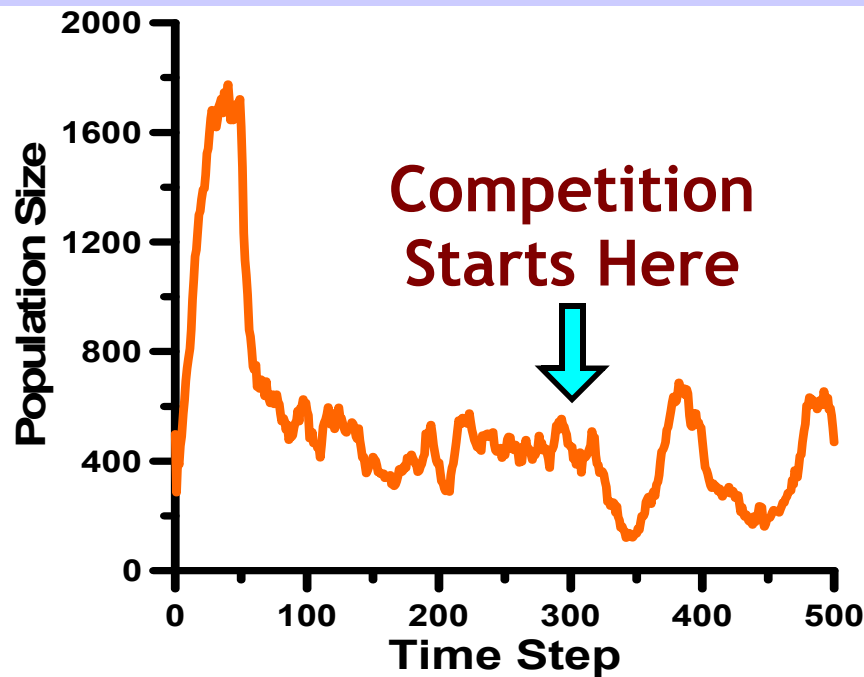
Add Competition to Beneficial Disturbance



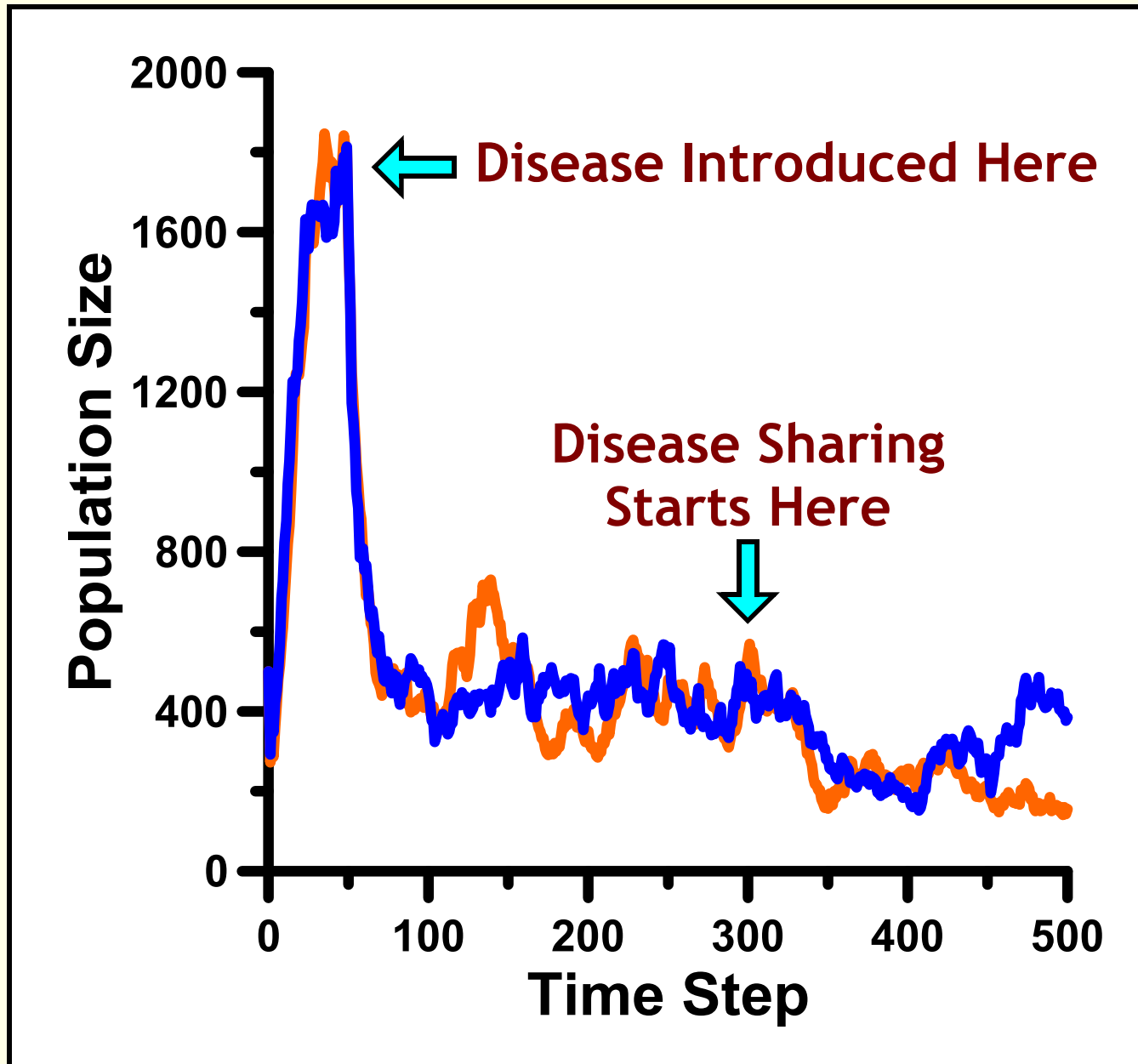
Disease + Competition



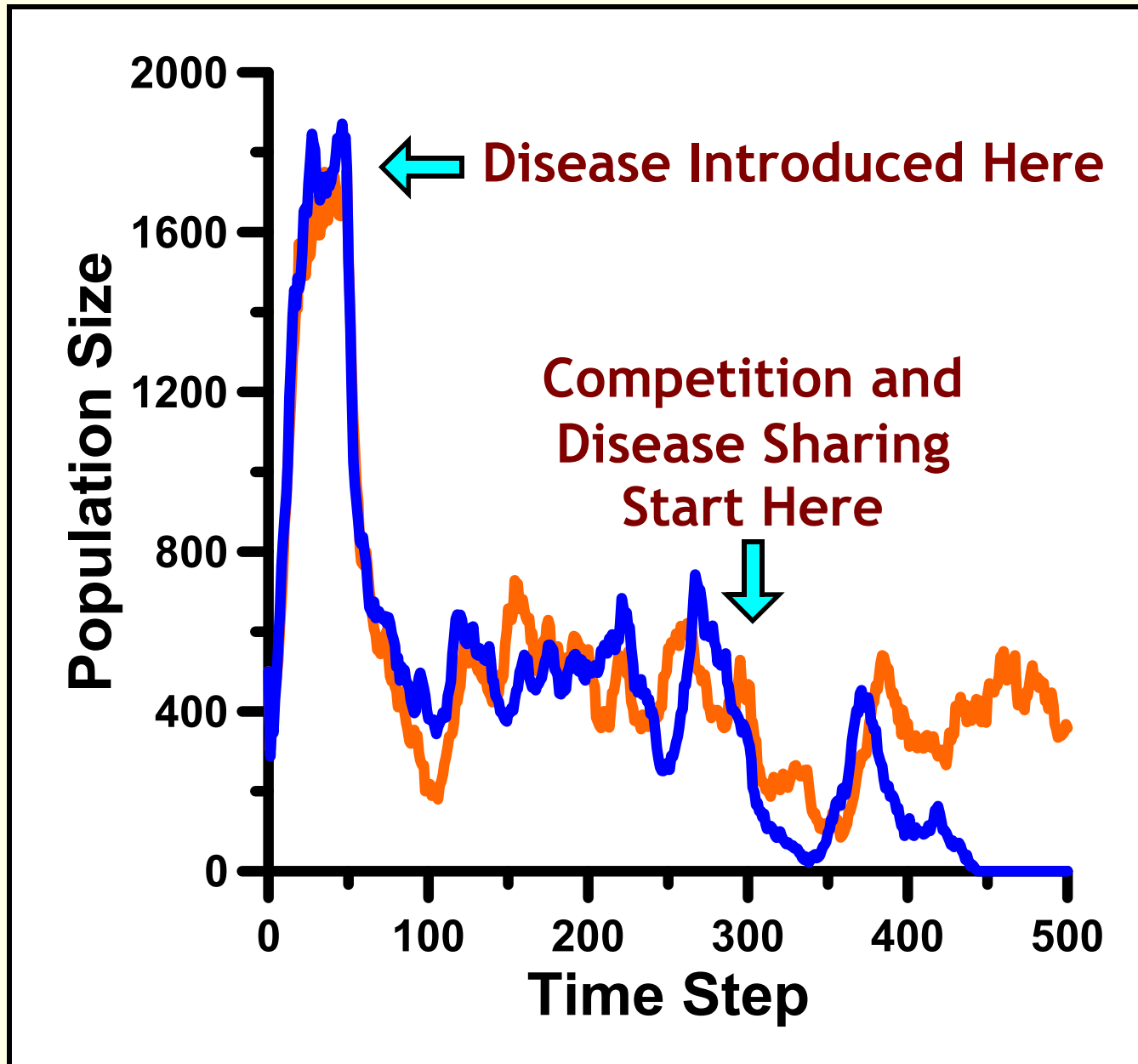
Disease + Competition



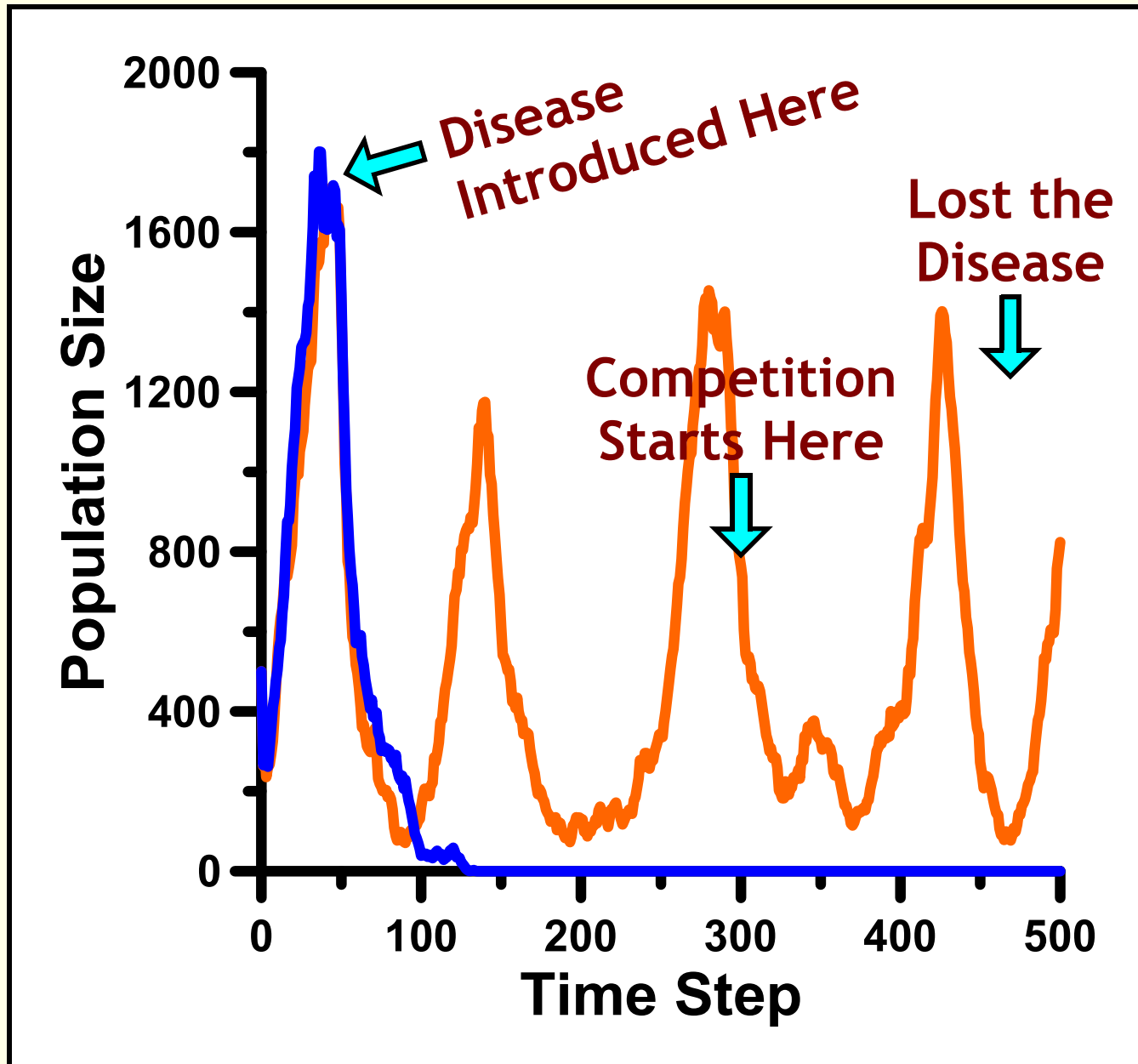
Disease Sharing [No Competition]



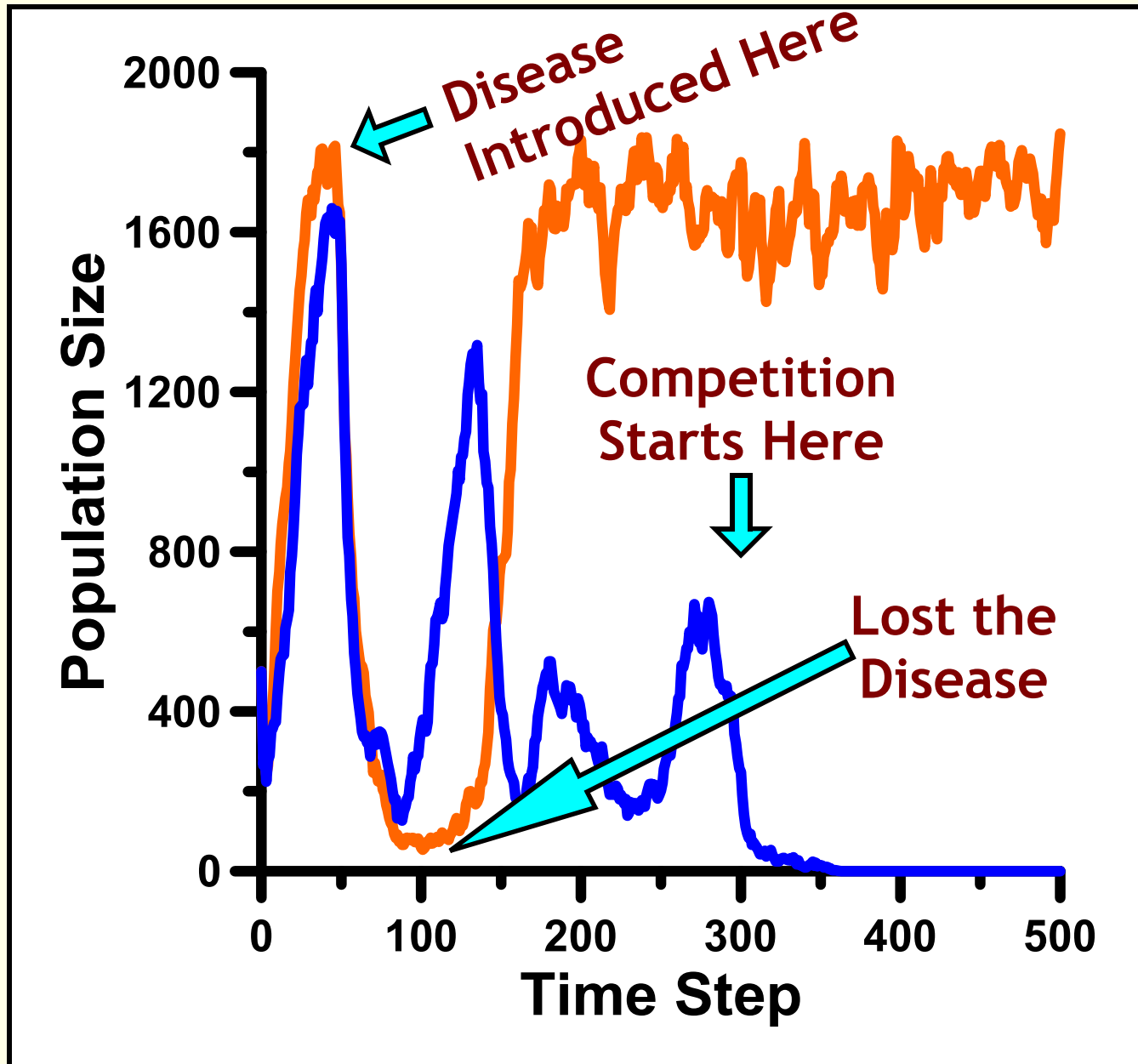
Competition + Sharing



**Disease (not shared) + Competition +
Beneficial Disturbance [1]**



**Disease (not shared) + Competition +
Beneficial Disturbance [2]**



Conclusions

- We have developed a flexible system for evaluating stressor interactions.
- Individual variation through traits is most important element of our design.
- This proof of concept illustrates a little of what can be done with the tools. Your use of these tools is encouraged.

Acknowledgements

Allen Brookes and Kevin Djang

US Environmental Protection Agency

SERDP (Project SI 1541)

**All of the collaborators who have
helped to improve the model design.**

www.epa.gov/hexsim

www.hexsim.net